A new multi-scale analytic algorithm for edge extraction of strawberry leaf images in natural light

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Abstract: In this study, a new algorithm was proposed for edge extraction of greenhouse strawberry leaf in natural light based on the 4-level daubechies 5 (‘db5’) wavelet decomposition. This algorithm adopts different segmentation methods for the reconstructed images at different scales to erase the external background and the internal leaf vein interference. There were two advantages of this method. One was that it can provide the abstraction from different spaces to express a same image. The other one was that some image features are hard to be acquired in some scale spaces, while the features are easy to be obtained in other scale spaces. In this image process methods, the Otsu threshold segmentation was to obtain the binary image areas, and the Canny segmentation is to obtain the accurate gradient edges, then the morphological methods and the logical calculus methods were to avoid the fragments inside the leaf area and the adhesions outside the leaf area. Since the strawberry leaf images were different respectively, and the greenhouse optical radiation and reflection may cause local non-uniform illumination of leaf image, the pseudo canny edges of leaf image ere divided into three categories in this research. The first category was the external pseudo canny edges area of the first layer reconstructed leaf image, the second category was the internal pseudo canny edges area in highlight of the third layer reconstructed leaf image, the third category was the internal pseudo canny edges area of significantly different grayscale of the third layer reconstructed leaf image. The different processing methods were constructed for the three kinds of different texture features based on the multi scale reconstructed images, then the complete and the accurate leaf edges without interference were obtained. Finally, the multi scale method was simplified and a remarkably effective segmentation algorithm was deduced for the greenhouse strawberry leaf in natural light.

Keywords: multi scale analysis, edge extraction, strawberry leaf images, canny edges, Otsu segmentation

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1 Introduction

Segmentation is a key part of image analysis in agricultural application. The accurate and the complete plant leaf edge information provides target region for the correct crop biomass obtainment. For example, there were researches in growth status detection, chlorophyll content, determination plant leaf diseases and insect pests early warning, as well as the leaf 3D shape reconstruction and the plant leaf area calculation. Strawberry has been widely cultivated in greenhouse due to its advantages such as short growth cycle, less disease, easy

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management, high nutritional value and high economic value, researches on greenhouse strawberry leaf image segmentation are important to the digital management.

At present, a lot of leaf image segmentation studies had been carried out in the specific environment of light. The image shape, the texture feature and the reflection absorption optical properties differed in thousands of ways[1,2]. In this study, a segmentation method of strawberry leaf in natural light based on wavelet analysis was deduced. This research aims at designing a quick and accurate edge detection algorithm of strawberry leaf images which are captured from remote video streaming in natural light conditions of greenhouse. In previous studies, the image enhancement, edge detection, threshold, morphological process and other image processing methods to segment the field jujube leaves from complex background had been integrated and satisfactory results were achieved[3-5]. However, the influences of leaves reflection, veins, and texture on jujube leaf segmentations were relatively smaller than those on strawberry segmentations. More factors in the segmentation algorithm of strawberry leaves in natural light should be considered.

Some researchers[6-8] had studied common maize and strawberry leaf disease with color image threshold segmentation approach for the automatic identification, then the automatic threshold segmentation results depend on the shoot light uniformity and the difference between target and background were pointed out. By analyzing the histogram of Hue channel between diseased and normal corn leaves, the single peak characteristics could be obtained by the prior knowledge to select more effective segmentation threshold. Other studies[9,10] firstly marked the connection of the components which solidity is greater than 0.9 of beans and weeds in the plant canopy image sets. The green channel clustering by the Gustafsen-Kessel method was adopted for other connected pieces. Then the solidity was used to choose the fitness function of genetic algorithm to reassemble the fragments, and the above process was repeated until all the connected domains marked, the final target region is the final marked component. Some more researchers[11-13] studied a near infrared remote sensing image analysis method. The red-green channel morphologically clustering was firstly used to CCD images under natural light conditions, and then the crop vein information was obtained by geometric difference between the original image and image after the morphologically opening operation to ensure the plant center by combining the center and the clustering information. The segmentation results can be gained finally. The studies in the usage of Otsu and the morphological erosion was to obtain the initial internal and external markers, and then the markers were used to control watershed over the segmentation of the plant leaves and the background [14].

Since the strawberry leaf images were respectively different under the non-uniform illumination in greenhouse optical radiation and reflection conditions, the real strawberry edge is conflict of the pseudo edges of its clear texture, which have the same gradient changes as the leaf vein and something in the background; therefore a single segmentation method of the strawberry leaf images was not feasible.

In consideration of the relationship of the light conditions, the shape of leaves targets and the complex background with segmentation algorithm, a strawberry leaf edge detection method was presented in natural light based on multi scale analysis[15,16], which analyzed the difference of edge and texture features between the different scale spaces images in this research. This method combined the scale space, canny edge detection, Otsu threshold segmentation and morphologically processing methods, to achieve the satisfied results of the strawberry leaf edge.

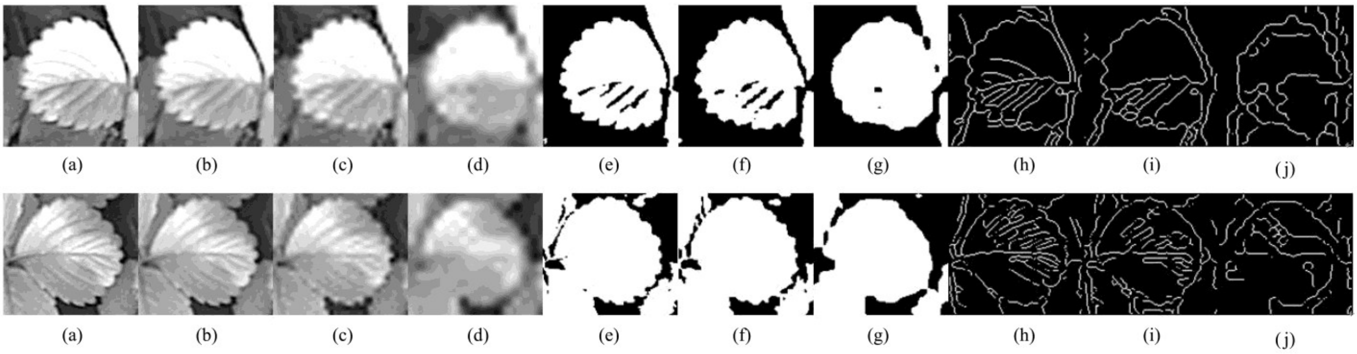
2 Materials and methods

The strawberry images used in this study were captured by a CMOS camera in natural light greenhouse.

Figure 1 The strawberry image in natural light greenhouse

2.1 The Multi scale space

Multi-scale image analysis is known as mathematical microscope, in the analytic process, the approximate images could be reconstructed from the detail and the abstraction of the different levels in the relative scale spaces separately[17]. The reconstructed images were used to analyze the different features of images and to obtain the edge of target area. Because the wavelet transformation has better local time-frequency analysis characteristics than Fourier transformation, thus, wavelet transformation is more flexible in the direction of selection, wavelet function selection, and time-frequency resolution selection[18]. Wavelet transformation was widely used in the field such as feature extraction, target recognition, signal processing, etc. The horizontal, vertical, and diagonal details and the approximate wavelet decomposition coefficients of image could be captured in the wavelet decomposition. The higher and the lower pass edge approximate images in arbitrary scales could be reconstructed with the approximate wavelet decomposition coefficients. By analyzing these higher and lower pass edge approximate images, the proper segmentation methods could be deduced. Generally, as shown in Figure 2, if the scale is higher, the information remained in the reconstructed image is lesser, the reconstructed image is fuzzier and the vein texture is lower.



(a) The original grayscale image; (b-d) The gray approximate images of 1-3 layers scale of wavelet reconstruction; (e-g) The results of OTSU segmentation of (b-d); (h-j) The results of canny edge detection of (b-d)

Figure 2 The higher and the lower pass edge approximate leaf images of strawberry in 1-3 layers scales

It could be found that, in the Otsu segmented results of higher scale reconstructed images, although the internal leaf holes were reduced with the decrease of the vein texture, the adhesions between the target and the background increased, and then the target position became fuzzier. The edges of the scale reconstructed images detected by Canny became less with the increase of scale. Obviously, a complete and an accurate edge could not be obtained by one of the Canny and Otsu segmentation only in one scale space.

In this study, the four-layers Daubechies 5 ('db5') wavelet decomposition was used to build the edge extraction algorithm based on the differences of the scales. The multi-scale analytic steps are shown as follows.

1) The first layer reconstructed image was Otsu segmented and an accurate target area was obtained, then the binary image results were morphologically eroded and the leaf outside region template was obtained to cut the adhesion and to erase the pseudo canny edge in the first dimension space.

2) The third layer reconstructed image which contains less vein texture features was Otsu segmented, and the rough leaf area could be obtained, then the rough leaf area could be taken as a mask. The third layer reconstructed image was segmented for the second time in the mask area, and the foreground and the background were morphologically processed separately, then the leaf internal region template could be obtained to erase the pseudo canny edge inside the leaf area.

3) Finally, the strawberry leaf canny edge image without the external and the internal pseudo edges interference was obtained by the logic operations.

2.2 The erasure of pseudo canny edges

Some factors apparently had impacts on segmentations, such as the uneven light, the contacts or the overlaps between leaves or weed, curled leaf shapes, etc., and all these factors might result in the delicate textures and the uneven inner grayscale levels in the foreground area and the background area of leaves, while the different parts of leaf image with the same surface normal vector had similar gray level, this might cause numerous similar canny edges. When the leaf image was segmented with canny operator, there will be many texture edges in the result image, some of them were inside the real leaf edge, and some of them were outside the real leaf edge. Based on the above analysis, the relative pseudo canny edge in the first layer reconstructed image was divided into three categories in this research:

1) The leaf external pseudo canny edges were regarded as the first category pseudo canny edges, which existed in the background area of the Otsu segmented binary image of the first layer reconstructed image in the 4 layers of 'db5' wavelet decomposition spaces.

2) The partial internal pseudo canny edges of leaf area were regarded as the second category pseudo edges, which occured in the foreground area of the second time Otsu segmented binary image of the third layer reconstructed image in the mask.

3) Another partial internal pseudo canny edges of leaf area were regarded as the third category pseudo edges, which appeared in the background area of the second time Otsu segmented binary image of the third layer reconstruction image in the mask, with the significantly different grayscale.

In consideration of the differences between the three kinds of different areas, the different processing methods were constructed to obtain the final real leaf canny edges without the three kinds of pseudo edges.

2.2.1 External contour process

The accuracy of the leaf edge was mainly owing to the process of Otsu segmenting of the first layer reconstructed image of the four-layer 'db5' wavelet, and to the process of erasing leaf external pseudo canny edge. The background area above was used as the first category area template to erase the redundant external pseudo canny edge, and the template kept a few pixels away from the real leaf edge with morphological operators to avoid incomplete leaf edges.

Therefore, the flow of the first category pseudo edges erasing was divided into three steps.

1) The first layer gray image after wavelet decomposition was reconstructed.

2) Canny edges were detected and the first layer reconstructed image was Otsu segmented to obtain the canny edges image and binary region image of the first layer reconstructed images.

3) The Otsu background area of the first layer reconstructed image was taken as the first category area template to erase the pseudo canny edges in the leaf external area by morphological and logical methods.

The Otsu segmentation of the first layer reconstructed image might cause the holes in the internal leaf area in Figure 4b. The foreground was eroded by the circular structure of 2 pixel radius and the holes were morphologically filled. Then it was eroded again by the circular structure of four pixel radius, and the largest area in the connected domains was morphologically dilated by circular structure of eight pixels radius to get the result image as external template and to be two pixels away from the leaf edges. The multiple erosions were to avoid expanding the internal leaf holes and extracting incomplete leaf area by disconnecting the adhesions between the leaf and background. The flow of the multiple erosions and the dilation to get external template is as follows in Figures 3 and 4.

It can be found from Figure 4 that the directly erosion of the binary area by six pixels structure may result in the expansion of the inner texture holes and the fragments of the leaf area, while the multiply erosion can disconnect adhesion without aggravating internal texture holes and obtain complete leaf area.

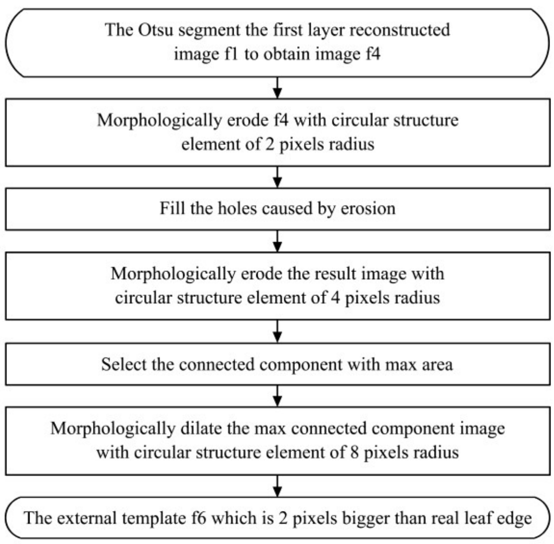


Figure 3 Flow chart of external contours module

(a) (b) (c) (d) (e) (f)

(a) The first layer reconstructed image; (b) The Otsu segmentation result of the first layer reconstructed image; (c) The result of directly eroding the '(b)' by the circle structure of six pixels radius; (d) The result of eroding first '(b)' with two pixels and filling the holes then eroding it again with four pixels; (e) The largest connected domain image by filling the holes in '(d)'; (f) The external template by expanding '(e)' with eight pixels

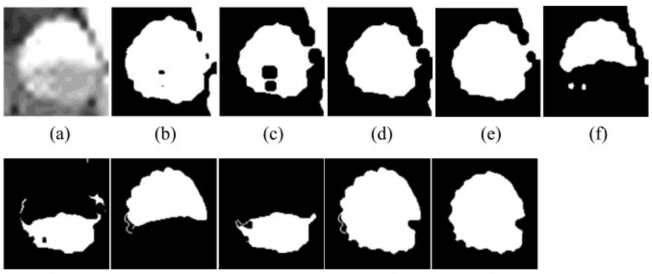
Figure 4 The external contour extracting steps

2.2.2 Internal contour process

The third layer reconstructed image was Otsu segmented for the first time, and the foreground area was morphologically eroded directly by circle structure of six pixels radius, then the holes were filled to obtain the largest connected domain as the mask. The foreground of the first time Otsu segmentation was eroded directly by six pixels to make sure that the mask is inside the leaf edge. Because the third layer reconstructed image had less texture and might keep the foreground leaf area more complete in the segmenting, then some adhesions with background in the results were allowed.

The third layer reconstructed image was Otsu segmented for the second time inside the mask area, and the foreground area was obtain to be the second category pseudo canny edge area, then the background area was the third category pseudo canny edge area.

The steps of the example leaf processing and flow are in Figures 5 and 6.



(g) (h) (i) (j) (k)

(a) The third wavelet layer reconstruction image f2; (b) The OTSU threshold segmentation result of '(a)'; (c) Using the circular structure of six pixels radius to corrode the '(b)'; (d) Filling the holes of '(c)' and corroding the result; (e) Expanding the largest connected foreground region of image '(d)' with the circle structure of three pixels radius; (f) The Second time Otsu threshold segmentation result of the third layer reconstructed image within the mask area of (e)'s foreground; (g) The remaining images after twice segmentation without image '(f)'; (h) The inner highlight (second category) area extracted from '(f)' and connected with canny edges; (i) The inner uneven (third category) area extracted from '(g)' and connected with canny edges; (j) The combination of '(h') and '(i)' areas; (k) The internal template by filling holes and corroding two pixels.

Figure 5 The internal contour steps

The flow chart of the whole internal contour is as shown in Figure 6.

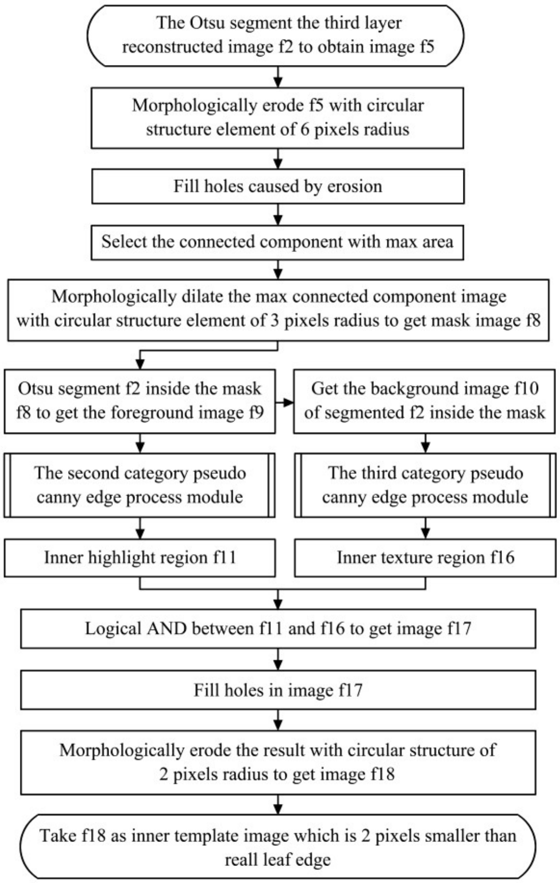


Figure 6 Flow chart of internal contours module

(1) The leaf internal uniform region

The third layer reconstructed image was segmented for the first time, and the foreground was taken as the mask to Otsu segment the third layer reconstructed image for the second time. The foreground area inside the mask was the second category area, which was named internal highlighted area with uniform grayscale. The segmentation fragments in the highlight target areas were stitched with corresponding inside fined canny edges. The steps of the second category pseudo edge process module are as follow:

① The third layer reconstruction image was Otsu segmented for the first time, and was morphologically eroded and filled, then the largest connected domain of the result was taken as a mask.

② The third layer reconstruction image was Otsu segmented for the second time inside the mask to get the foreground area image.

③ The foreground area image of the second time Otsu segmentation logic XORed with the canny edges of the first layer reconstructed image to stitch the fragments in the foreground, and then was morphologically filled.

The largest connected domain was selected as the internal highlight area template.

④ The internal highlight area template logic ANDed with canny edge to erase the pseudo canny edges inside the leaf internal highlight area. The steps and flow are as follows in Figures 7 and 8.

The flow chart of the second category region is as shown in Figure 7.

The instance graphs of internal uniform highlight region processing steps are as shown in Figure 8.

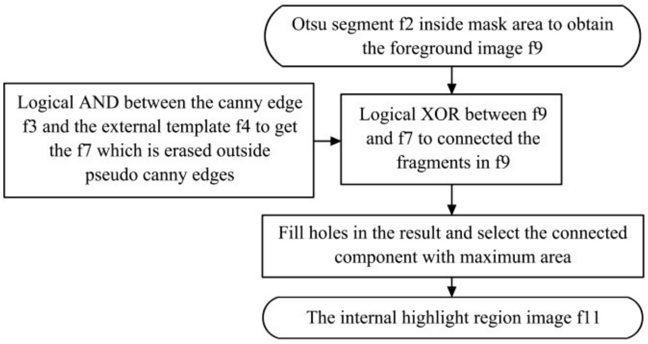
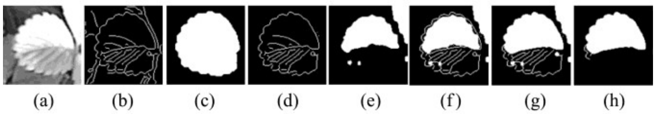


Figure 7 Flow chart of the second category area pseudo edge processing



(a) The first layer reconstructed image f1; (b) The Canny edge image f3of the first layer reconstructed image f1; (c) The external template f4; (d) The image f7 which is erased external pseudo canny edge; (e) The foreground image f9 of the second time Otsu segmented f2 inside the mask f8; (f) Logical XOR between f9 and f7; (g) Filling the holes; (h) The internal highlight region template image f11.

Figure 8 Flow chart of the second category area

(2) The leaf internal uneven region

The background area of the second time Otsu segmentation of the third layer reconstructed image was the third category pseudo canny edge area, which was the leaf internal area with uneven grayscale, and the grayscale was close to background somewhere, then the grayscale might result in adhesions. The steps of the third category pseudo canny edge process module are as followings:

① The canny edges were morphologically dilated by structure of three pixels radius, and the finely-divided edges were connected, then the dilated canny edge were morphologically eroded back to obtain a thin and connected canny edge.

② The background area of the second time Otsu segmentation inside the mask were morphologically eroded, then the fragments were stitched with the connected canny edge and the leaf outside adhesions were disconnected by the logic operations.

③ The results above were morphologically filled and eroded, and the largest connected domain was taken as the third category area template.

The flow chart of the third category internal region is as shown in Figure 9.

The instance graphs of uneven grayscale region processing steps are as shown in Figure 10.

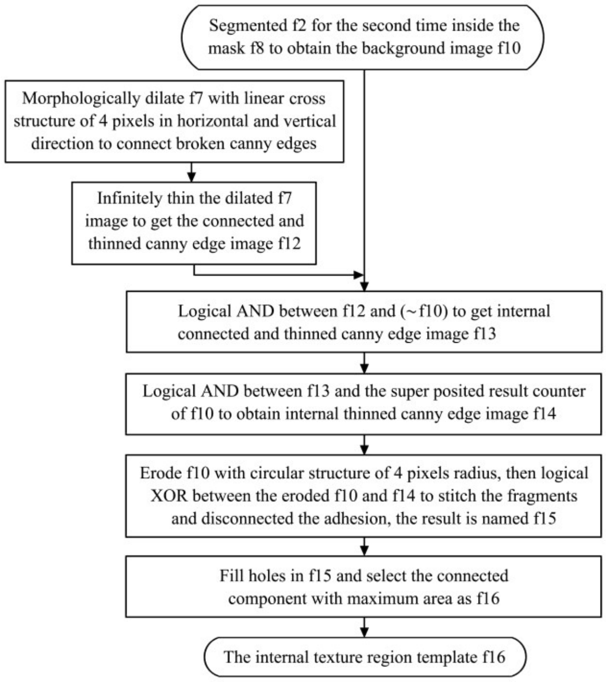
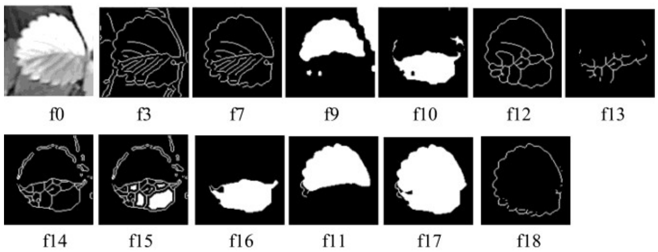


Figure 9 Flow chart of the third category area pseudo edge processing



(f0) The first layer reconstructed image f1; (f3) The canny detection result edges of the first-scale reconstructed image; (f7) The edge image which removed of external pseudo external edge; (f9) The highlight region obtained by twice OTSU; (f10) The other part besides highlight region in the leaf; (f11) The target area by using the second category of pseudo-edge handle program; (f12) The canny edge image after mutual connecting and refining; (f13) The refining edge within f10; (f14) The superposition of the f10 border and the f13 inner edge; (f15) The segmentation result of corroded f10 by using the edges of f14; (f16) The largest connected region after filling f15 holes; (f17) The inner template used to remove the inner highlighting and texture; (f18) The final result.

Figure 10 The instance graph of the third category area pseudo edge processing

(3) The whole leaf edge obtaining

Combining the second and the third category areas with logical operators, the complete leaf edge was obtained. The area of combination was morphologically eroded, and the results were taken as complete internal template which was one or two pixels smaller than real leaf canny edge.

Then the internal template logical operated with the canny edges image of the first layer reconstructed image to erase internal pseudo canny edge and obtain the whole leaf canny edge without pseudo edges.

2.2.3 The remarks

(1) The largest connected domain

The original image was cut into leaf size sub-images, therefore the sub-image size was similar to the leaf size, therefore the area of the complete leaf in the sub-image was dominant and centered. The largest connected domain in the foreground or the background of Otsu segmentation image was assumed to be the leaf area in the sub-image according to the grayscale conditions of the sub-images. If the background was leaf area, the process of background and foreground in the first category area would be exchanged.

(2) The causes of the second and third category pseudo edge area

The leaf is not a plane, and the causes of pseudo canny edges of the second category area are the slightly folding or curling of leaf surface, that make grayscale affected by illumination and appear highlight. The second and the third category pseudo edge area was the leaf internal area which was the foreground and the background of the second time Otsu segmentation. Some of the background grayscale of internal leaf area was close to the external leaf area, and this is the main reason of adhesions (As shown in Figure 2, the first line in graph a).

(3) The correlated operations of the second and the third category area

(a) The leaf internal template wass one or two pixels smaller than the leaf canny edges, which was obtained from the first time Otsu segmented foreground of the third layer reconstruction image. The template might include some background contacted with the leaf, and the internal template in the foreground area would be built in two stages.

(b) The first time Otsu segmented foreground area was firstly taken as the mask and Otsu segment the masked third layer reconstruction image again. Then the foreground area of the second time Otsu segmentation was the internal second category area, which is highlight and even. The background of the second time Otsu segmentation within the mask was the third category area, which gray was remarkable different.

(c) The two category area was stitched by the extracted canny edges respectively, then the two category area were combined, and the complete internal template was obtained, then the outside adhesions were disconnected.

The first time Otsu segmented image foreground of the third layer reconstruction image was morphologically eroded to obtain an area as a mask which was one or two pixels smaller than the leaf edge somewhere. Then the inner mask area of the third layer reconstruction image was segmented by Otsu again and the foreground and background in the result were regard as the second and the third category area. The flow and steps are shown as Figures 6 and 7.

2.3 Complete algorithm process

The steps of the general algorithm of strawberry leaf edge extracting are as follows, the flow is shown in Figures 11 and 12.

(1) The color sub-image was changed into gray image, and then the sub-image was de-noised with wiener filter.

(2) The de-noised image f0 was decomposed with 4 levels ‘db5’ wavelet, and the first layer image f1 and the third layer image f2 of the four-layer ’db5’ wavelet decomposition was reconstructed.

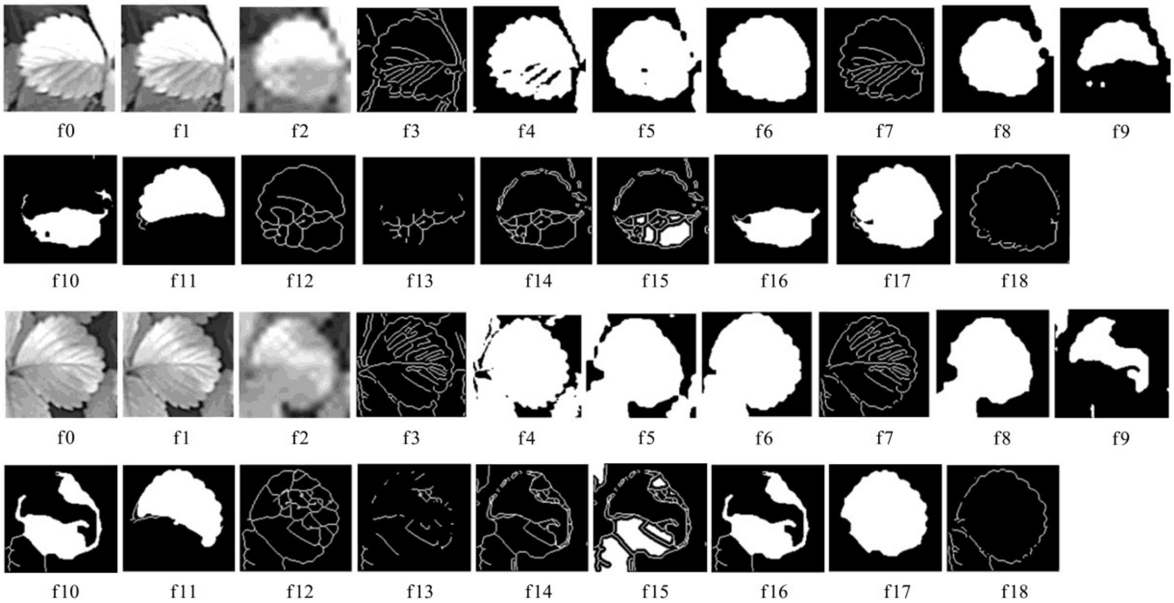
(3)The canny edges of f1 were detected and f1 was Otsu threshold segmented, then f2 was Otsu threshold segment, too. The results were named f3, f4, and f5 respectively.

(4) The external template area f6 was obtained by the external contour program from the first-scale threshold image f4, which aimed at erasing external pseudo edge. The inner template area f18 was obtained by the inner contour program from the third-scale threshold image f5, which aimed at erasing inner pseudo edge.

(5) The edge image f7=f3 & (~f6) was obtained to erase external pseudo canny edge by logic operation.

(6) The final leaf edge image f18=(~f17) & f7 was obtained.

The whole algorithm process is described by images as follows in Figure 11, and the flow steps are shown in Figure 12.



(f0) The original gray-scale leaf image; (f1) The first layer reconstruction image; (f2) The third layer reconstruction image; (f3) The Canny edge detection result of the first-scale reconstructed image; (f4) The Otsu threshold segmentation result on f1; (f5) The Otsu threshold segmentation result on f2; (f6) The external template area; (f7) The canny edges which are removed external pseudo edges; (f8) The mask obtained by Otsu segmentation and morphology result of f2; (f9) The highlight region obtained by twice Otsu; (f10) The other part besides highlight region of the mask f8; (f11) The internal high light area connected by f7 canny edges and filled the holes; (f12) The refined canny edges image f7 after morphology expanded connecting; (f13) The refined edges within f10; (f14) The superposition of the f10 border and the f13 inner edges; (f15) The segmentation result of corroded f10 by f14 edges; (f16) The largest connected region after filling f15 holes; (f17) The inner template combined by f11 and f16 after corroded; (f18) The final f3 canny edges segmented by f6 and f17.

Figure 11 The whole processing steps of the leaves

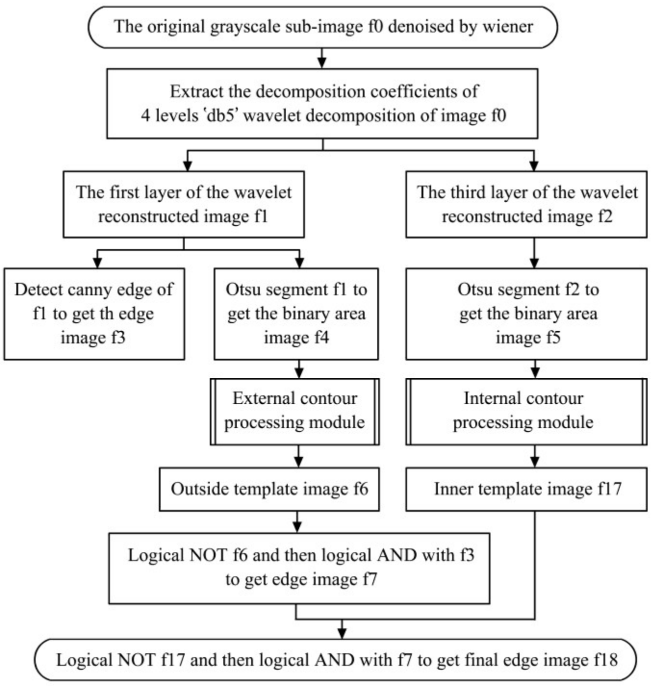


Figure 12 Overall flow chart of the multi-scale algorithm

3 Results and discussion

In this study, all strawberry leaf images were taken in natural light by a CMOS camera.

Considering all the situations presented above, it was realized that the method based on wavelet analysis was to effectively solve the problem of the strawberry leaf segmentations, which were influenced by illumination, overlapping, and curling of leaves in natural scene. Because the scale operation cost considerable computing resources of computer system, the above segmentation method was simplified to avoid wavelet calculating; meanwhile the wavelet analysis methods deduced above were used to directly segment the original grayscale images with some changes.

3.1 The comparison of different segmentation methods

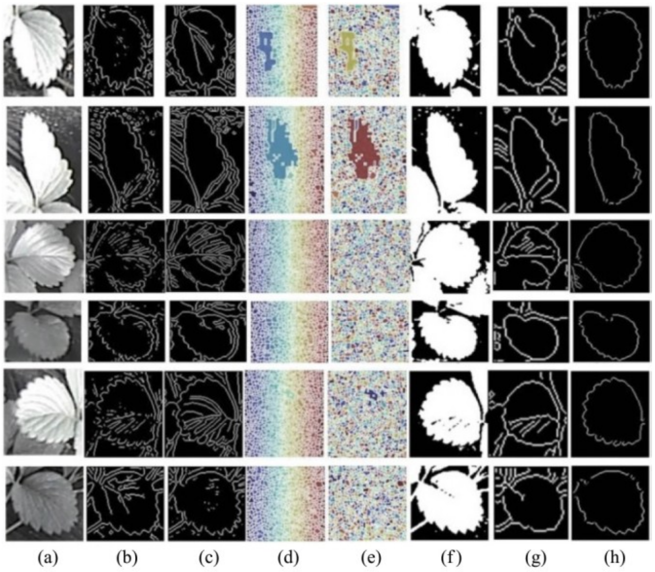
Through a set of comparison experiments, the differences between this segmentation method and the other common methods are shown in Figure 13.

The comparison experiment results are as follows.

The edges detected by Gauss Laplace differential operator were fracture and broken mostly. Serious adhesions existed among the leaves, tree branches and other things in leaf background.

Canny method could detect the continuous and only edges, and the result contained many other severe gradient changes caused by inner texture, petiole, and tree branches.

Direct watershed method had serious phenomenon of over segmentation. Edge submerged in noise or other signals were due to uneven illumination.



(a) The original grayscale leaf image; (b) The Gauss Laplace edge detection algorithm results; (c) The Canny adaptive edge detection algorithm results; (d) The direct use of watershed algorithm results; (e) The Marker-controlled watershed segmentation results; (f) The Otsu automatic threshold segmentation algorithm results; (g) The Wavelet packet edge detection results; (h) The results of the segmentation algorithm used in this paper

Figure 13 Comparative experiment results of different segementation methods

The improved-watershed segmentation method is based on morphological markers. Compared with direct watershed, it has been greatly improved, but for greenhouse strawberry leaves, because of the complex background and imaging condition, the improved watershed method existed phenomenon of dividing target into several fragments.

Otsu segmentation method might cause adhesions and internal holes, which were due to grayscale difference in the target, background, and internal texture of leaf.

Wavelet packet method could obtain continuous but sticky edges; meanwhile this method consumed more computing resource than the other methods.

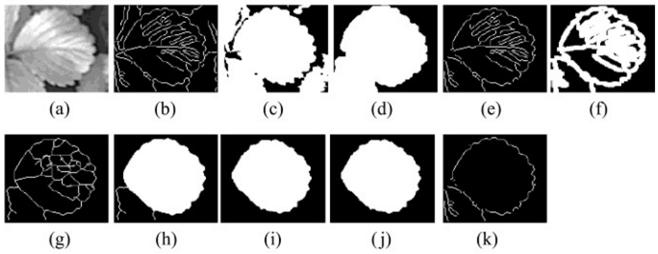
The deduced algorithm in this research, could obtain the complete and the accurate edges of strawberry leaf in natural light, and the edges were less interfered by the external background, the internal texture and the uneven illumination. The pseudo canny edges inside or outside the real leaf edge were erased almost completely.

The comparison experiment results showed that the algorithm in this research was significantly effective.

3.2 The simplified segmentation algorithm

Because the scale operation cost considerable computing resources, so the directly applying of the scale analysis algorithm to the original gray image came into consideration. The segmentation algorithm based on the scale reconstruction was improved, and was used in segmenting the original gray image.

The simplified segmentation process inherited the multi scale segmentation methods, which only divided the pseudo canny edge area into two categories. One was the external leaf pseudo edge area, which was the same as the external pseudo canny edge process in the first layer reconstructed image above. The other one was the internal leaf pseudo edge area, which was the same as the third category pseudo edges process in the third layer reconstructed image above. The simplified algorithm is as follows in Figure 14, the segmentation showed remarkably effective.



(a) The gray image after denoising; (b) The Canny edge detection image; (c) The OtsuThreshold segmentation image; (d) The external template after morphological operations; (e) The canny edge after removal of external pseudo edge; (f) The continuous and uninterrupted edge by morphological expansion; (g) The approximate edge after unlimited elaboration; (h) The approximate edge image holes after filling and elaboration; (i) Obtain the inner area smaller two pixels than the actual edge by morphology corrosion; (j) Regard the largest connected domain as the internal template after filling the holes;(k) The final edge image.

Figure 14 Simplified segmentation algorithm process based on directly applying wavelet analysis process

In the simplified algorithm, we fully considered the complication of segmentation, for example, the texture features of leaf inside area were complex, while the external template might be not ideal but effective. In the scale analysis, the third scale wavelet reconstructed image could be used in Otsu segmentation to obtain the complete external template. But if the external template of leaf area could not be obtained completely, then leaf edge could not be obtained completely in the simplified method. If that occasion happened, the wavelet analysis process under the complex external texture should not be omitted in the edge extraction process.

4 Conclusions

The multi-scale algorithm of extraction strawberry leaf edge was proved to be effective and efficient by the experiments, and the contributions of the article are in the following.

Based on the multi scale wavelet analysis studies of the strawberry leaf in natural light, the pseudo canny edges of leaf sub-image were classified with Otsu operator into three categories, which were caused by the external background, the internal uniform highlight area, and the internal uneven grayscale area.

The different methods were deduced in the different scale spaces for erasing pseudo canny edges and obtaining the complete and the accurate leaf canny edge.

A new line cross structure was built in the processing of the third category area, which was used to morphologically eroding the binary image.

The fragments of Otsu segmentation were stitched with the fined canny edges to conjoin the foreground or background areas to be a whole component separately.

The simplified algorithm was directly used in segmenting the original grayscale leaf image to save computing resource. The experiments showed that the simplified method is effective excepting the occasion of the incomplete external template.

The leaf edge extraction algorithm can be used in the analysis of leaf pest and disease, the calculation of leaf area, the monitoring of nutrition and growth status, and then we could realize digital management of orchards in our future work.

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